Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

OZONE AS A DISINFECTANT IN WATER PURIFICATION[1]

By Joseph W. Ellms[2]

Ozone was first observed by the Dutch chemist Van Marum in 1785, while operating a static electrical machine. In 1840, Schoenbein while investigating the properties of the gases produced in electrolyzing water and electrifying air, noted the odor and oxidizing properties of the gas and gave it the name of "ozone," because of its peculiar odor. It was not until the results of Soret's work in 1865 were known, that scientists agreed that ozone was tri-atomic oxygen, although it had been generally held that it was some form of oxygen.

Ozone is an unstable gas requiring a large amount of energy for its formation (34,000 calories). It is but slightly soluble in water, and undergoes decomposition when heated. When strongly ozonized oxygen is liquefied and the product subjected to fractional distillation, a mixture of ozone and oxygen results, of which about 85 per cent is ozone. The factors governing the "ozone-oxygen system" are none too well understood. The state of equilibrium which exists in a mixture of the two gases is dependent upon several factors, such as temperature, pressure, and electrical conditions that are extremely complex.

Ozone is an extremely energetic oxidizing agent. It attacks many inorganic oxidizable substances readily, and is particularly destructive of organic matter even at low temperatures. Its value as a bactericidal agent is probably due to this property, and is the reason for its use in the disinfection of drinking water.

For practical purposes, the production of ozone can best be effected by certain forms of electrical discharges through oxygen gas or through air, which, of course, consists in part of oxygen. It may be well to describe the nature of these discharges so that the technical difficulties of the practical production of ozone will be better appreciated.

---

[1] Read before the Central States Section. Discussions of this paper are requested, and should be sent to the Editor.

[2] Consulting Sanitary Engineer, Cleveland, Ohio.

The phenomena of an electrical discharge through a gas are complicated. Ordinarily gases are non-conductors, but may become conductors under certain physical and electrical conditions brought about by the flow of the current through them. When two electrodes are separated by a gas and connected to some source of high tension electricity, and between them the potential difference is being gradually increased, there is first produced an invisible electrical discharge which gradually becomes visible by a glow upon one of the electrodes. As the potential difference increases the corona effect is produced, which changes to the true brush discharge. It is this latter form of discharge that is regarded as the most effective in the production of ozone. By still further increasing the potential difference between the electrodes there is formed in succession the spark discharge, the flame and finally the well known electric arc.

The brush discharge is of a dark blue violet color and is accompanied by a peculiar hissing sound and the "electric wind," which latter, according to J. J. Thomson, is due to a current of electrified ions that set the air in the vicinity of the discharge in motion. Brush discharges are readily formed on electrodes having sharp points or roughened edges. Alternating or direct current may be used, but usually the alternating current is preferable since it may be obtained more readily under high tension. A better production of ozone appears to be obtained with alternating currents of high frequency. A 500 cycle alternating current is more commonly used in ozone installations than one with lower frequencies.

It has been found, as a result of much experimentation, that the use of a dielectric between the electrodes increases the yield of ozone. In other words, imposing even greater resistance than that offered by the air itself, effects a larger production of ozone by the discharge. Dielectrics are made from various substances, such as glass, mica, fused quartz and baekelite. While many other substances will act as dielectrics, the above named include the practical materials available in ozone work.

It will probable be appreciated from the little that has been cited of the complex character of the phenomena of ozone production that the pressure, temperature and humidity of the air being electrified, the form, size, spacing and material of the electrodes, the kind of current employed, the frequency in the case of an alternating current, the voltage, amperage and other secondary influences of an electrical nature in general, and the kind and arrangement of the dielectrics employed, are factors that must all be given careful consideration in an efficient ozone apparatus. A brief description of one or two of the ozonizers that have been developed and have been used may be of interest.

There are two general types of ozone apparatus. The Siemens-Halske ozonizers are of the vacuum tube type, in which air is drawn through an annular space across which high-tension electrical discharges occur. An inside metallic cylinder acts as one electrode. It is covered by a slightly larger tube of glass covered with tin foil. The electrodes are water cooled. The General Electric and the Gerard apparatus are of the tube type also. The Small-Linder, Abraham-Marmier and Vosmaer apparatus use plate forms of electrodes and dielectrics. In some cases their electrodes are hollow and water cooled, but in others this cooling is not attempted. Voltages varying from 2000 or 3000 to 50,000 or 60,000 have been used in various ozonizers, but from 10,000 to 20,000 volts are more commonly employed. The yield of ozone increases with an increase in wattage for any given area of electrodes, that is, with the density of the current per unit of area.

The application of the ozonized air to water, where the ozone is to act as a disinfecting agent, has been given considerable attention by investigators, but much more study of the problem is needed. In some cases the flowing water is used to suck the ozonized air through the ozone generator and into the water to be treated. This method is not susceptible of very close control. Another method consists in pumping the ozonized air into the bottom of towers down through which the water descends. A modification of this latter method consists in placing the air compressor back of the ozonizer, thereby avoiding handling the corrosive gas in the compressor. In this case the ozonizer must be in a container that will withstand the air pressure required to overcome the hydrostatic head of the water columns and the friction head resulting from the flow of the air through pipes and towers. A third but expensive method has been used in which the water has been sprayed into the atmosphere of ozonized air. Baffled towers where the counter-current system is used have not proven very successful. A great deal is yet to be learned regarding the proper method of distributing the ozonized air at the bottom of the column of water, so that a maximum absorption of ozone may be effected.

Since the expenditure of so much electrical energy in ozonizing the air creates more or less heat, and in consequence subsequent decomposition of the ozone formed, cooling and drying the air by refrigeration have been usually resorted to.

In small plants, passing the air over chemicals that would absorb the moisture, has also been successfully utilized. The yield of ozone apparatus naturally varies greatly, depending upon the manner in which the air is handled both before, during and after the passage of the gas through the ozonizer. Russell Spaulding in a report to the New York State Department of Health in 1913, very concisely states the desirable features of a good ozonizing apparatus. He estimates the theoretical yield of ozone for an expenditure of 1 kilowatt of electrical energy to be 1386 grams. Since the actual yields of apparatus will vary all the way from 10 to 60 grams per kilowatt, it is evident that their efficiencies are very low. Mr. Spaulding summarizes his conclusions as follows:

> To summarize, then, the main desiderata in generating ozone are:
>
> 1. A supply of alternating electric current at low cost.
> 2. An efficient transformer to obtain high tension.
> 3. Ozone electrodes that *do not* generate heat to
>   *a.* Disrupt the dielectrics.
>   *b.* Cause reversion of ozone to oxygen.
>   *c.* Require external means for cooling.
> 4. Ozone electrodes that will approach the theoretical efficiency much more closely than the various systems now in use.

To this the author would add, that unless the ozonized air is effectively applied to the water to be disinfected, that is, unless practically 100 per cent absorption of the ozone by the water is effected, the over-all efficiency of the entire apparatus may still be far from satisfactory. This phase of the subject still warrants considerable investigation.

The ability of ozone to reduce the bacterial content of a water has been too frequently demonstrated to doubt its inherent disinfecting properties. Nevertheless, it has its limitations in this direction like other disinfectants. In waters containing too large an amount of organic matter some of the bacteria may escape being killed. Pathogenic organisms probably are more readily killed than the ordinary water forms, because of the unfavorable conditions imposed upon them in the water, as well as from the destructive effect of the disinfectant. Spore-forming bacteria may also escape destruction. Ozone, because of its strong oxidizing powers, has the merit of being able to oxidize and remove tastes and odors due to organic matter in suspension or solution, and to reduce the color due to vegetable stain. If ferrous iron exists in a water, it is able to oxidize the iron to the ferric condition, in which form it is practically insoluble, and hence may be removed by sedimentation and filtration.

In conclusion, it may be well to point out that ozone used as a disinfecting agent is no more a cure-all for a polluted water supply than are other disinfecting agents that are at present more widely employed. As a supplement to filtration processes ozone can be used with good effect, and thereby render the water safer for drinking purposes. That the process needs investigation and scientific development in order to make it economical and efficient, cannot be denied by its most ardent advocates. When such a development is brought about, its use in the purification of water will become more general and its points of real merit better appreciated.